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(54) Fiber optic diffusers and method for manufacture of the same

Faseroptisches Streuelement und zugehöriges Herstellungsverfahren

Diffuseur à fibre optique et procédé pour sa fabrication

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Description

BACKGROUND OF THE INVENTION

This invention relates to a fiber optic apparatus for producing an approximately uniform scattered light output, and particularly to improvements on two types of fiberoptic diffusers which can be used in a biological environment, and methods of manufacturing the same.

The method known as "photodynamic therapy" (PDT) has been widely used in recent years in treatment for cancers or tumors, and other diseases in humans and even in animals. Reference is made to U.S. Patent No. 4,889,129 for a discussion of particulars of one such PDT method and apparatus for practicing the method. There are three types of optical devices which are mainly used in PDT for light distribution at the treating region. The fiber optic microlens is one type of device which can transfer a divergent light beam to an area of accessible tissue surfaces. The fiber optic cylindrical diffuser or "line source" is another type which has a cylindrical scattering pattern of light output with respect to the central axis of the optical fiber, and can be used in a cylindrical geometry for application to areas such as a bronchus or esophagus. The fiber optic spherical diffuser or "light bulb" is the third type of device which produces a spherical scattering light field. The spherical diffuser is usually applied in treatment to approximately spherical cavities, e.g. the bladder or a surgically created cavity resulting from the resection of the bulk of a tumor.

A typical example of a fiber optic cylindrical diffuser and a method of making the same is disclosed in U.S. Patent No. 4,660,925 issued on April 28, 1987 to James S. McCaughen, Jr. The cylindrical diffuser disclosed by the MaCaughan patent includes an optical fiber with an exposed core portion at one end, a scattering medium coated on the exposed core portion and on the sheathing of the fiber adjacent thereto, and an end-open tube adhered on the scattering medium. The process of manufacturing the diffuser mainly includes the steps of stripping the cladding and sheathing of the fiber at one end of the fiber to provide a length of exposed fiber core, polishing the exposed core, coating the exposed core and the adjacent sheathing with a scattering medium, tightly inserting the scattering medium into the tube, filling interstices between the earlier coated scattering medium and the tube with the scattering medium, and excluding the entrapped air.

EP-A-0 299 448 discloses a fiber optic device for the transmission and lateral irradiation of laser energy comprising an optical fiber having an outlet and which, after removing its coating, is covered with a microcapsule. The microcapsule is transparent to laser radiation and has a substantially toroidal thickened portion surrounding the end. Thus, the microcapsule is arranged to provide a "corolla-shaped" output laser beam that is desirable for the purposes of angioplasty.

A typical fiber optic spherical diffuser and a method of making the same are shown by the U.S. Patent No. 4,693,556 issued on September 15, 1987 to James S McCaughan, Jr. The method mainly includes the steps of removing the cladding and sheathing of an optical fiber at one end to provide an exposed core portion, polishing the exposed core portion, and coating the exposed core portion and the adjacent sheathing of the fiber layer by layer with a scattering medium until a scattering sphere is formed.

In photodynamic therapy, the basic requirements for the fiber optic diffusers are that the light distribution must be as uniform as possible within a volume of tissue containing a tumor, and the mechanical properties must be reliable. If the fiber optical diffuser assembly breaks on insertion or during treatment, the light distribution will be inadequate at best. Furthermore, there is a possibility that a piece of the broken fiber will be left behind and if elevated oxygen concentration is present the danger of fire exists because of the higher power density present at the broken end of the fiber. In addition, rigidity of the fiber optic diffuser is also an important requirement in PDT. This is because the path of the fiber assembly in a channel of a flexible endoscope and in a tumor should be controlled by the direction of insertion rather than the irregular mechanical properties of the tissue or tumor. It is also desirable that the fiber optic diffusers have a low power loss and maximum power handling ability.

These requirements are not well satisfied by the conventional devices due to the shortcomings in their structures or the methods of making them.

The present invention is an improvement on the prior fiberoptic diffusers including the prior fiberoptic cylindrical diffusers and fiberoptic spherical diffusers, and on the methods of manufacturing the same.

OBJECT OF THE INVENTION

It is an object of the present invention to provide a fiber optic diffuser which has an approximately uniform scattering light output and good mechanical properties.

It is another object of the present invention to provide a fiber optic diffuser for use in a biological environment which has good optical properties and good mechanical properties.

It is still another object of the present invention to provide methods of manufacturing the fiber optic diffusers of the present invention which simplify the conventional process.

It is still another object of the present invention to provide a fiber optic cylindrical diffuser having an approximately uniform light output in a cylindrical scattering pattern with respect to the central axis of the fiber, and good mechanical properties, and a method of making the same.

It is still another object of the present invention to provide a fiber optic cylindrical diffuser with a low enough power loss, which can handle up to at least 600 mw/cm of 630 nm light continuously without damage,

and has a good mechanical strength and rigidity to allow a smooth insertion of the fiber assembly through the biopy channel of a flexible endoscope and into a tumor along a straight pass.

It is a further object of the present invention to provide a fiber optic spherical diffuser with an approximately uniform light output in a spherical scattering pattern, and good mechanical properties, and a method of making the same.

It is still a further object of the present invention to provide a fiber optic spherical diffuser with sufficiently low power loss, which can handle continuous power levels of at least three watts of 630 nm light without being damaged, and has good physical properties to withstand cold sterilization and to allow a smooth pass through a cytoscope.

It is still a further object of the present invention to provide a scatter composition which can be used in the fiber optic diffusers with improved optical properties.

These and still further objects of the present invention will become apparent hereinafter.

BRIEF SUMMARY OF THE INVENTION

This invention relates to improvements on the fiberoptic diffusers for use in PDT. The present invention discloses a fiberoptic diffuser, comprising an optical fiber with a fiber core and a jacket for delivering light energy, the pattern of radiated light being nearly uniform in intensity in a cylindrical pattern with respect to the central axis of said optical fiber, said optical fiber including a jacket-stripped core tip portion, a sleeve means enclosing said fiber tip portion without touching the same and fixed on the fiber jacket adjacent to said fiber tip portion; wherein said sleeve means has a closed end head portion and an opened end portion fixed on the fiber jacket adjacent to said- fiber tip portion, and wherein said sleeve means is in threaded connection with said fiber jacket.

The present invention also discloses a spherical fiberoptic diffuser for dispersing light in a spherical scattering pattern, comprising an optical fiber with a jacket-stripped bare core tip at one end and a scattering medium enclosing said bare core tip in a spherical form, wherein a cylindrical bushing means is provided which circumferentially surrounds said bare core tip without touching it and is fixed on the fiber jacket adjacent to said bare core tip portion, wherein said bushing means is in threaded connection with said fiber jacket, and wherein said scattering medium encloses and is in contact with a portion of said bushing means and said bare core tip.

Moreover, the present invention discloses methods for manufacturing such fiberoptic diffusers.

Advantageous versions are given in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a cross-sectional view of a fiber optic cylindrical diffuser of the present invention.

Figures 2A, 2B and 2C show cross-sectional views of three embodiments of the preferred tapered head of the sleeve member used in a fiber optic cylindrical diffuser of the present invention.

Figure 3 is a cross-sectional view of an alternate embodiment of a fiber optic cylindrical diffuser in accordance with the present invention.

Figure 4 is a cross-sectional view of a preferred embodiment of a fiber optic spherical diffuser of the present invention.

Figure 5 is a cross-sectional view of a fiber-bushing assembly and a preferred connection between the bushing member and the fiber jacket.

Figure 6 is a cross-sectional view of an example of a metal mold for making the silicon rubber mold with multi-cavities.

Figure 7 shows schematically a preferred process of making the scattering sphere of the fiber optic spherical diffuser of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings with greater particularity, there is shown in Fig. 1 a fiber optic cylindrical diffuser 20. The cylindrical diffuser 20 includes a longitudinally located optical fiber 10 with a bare fiber core tip 15 coated with a layer of scattering medium 16, and a sleeve 18 enclosing the coated core tip without touching the scattering medium 16 and fixed on the jacket of the fiber 10 adjacent to the core tip 15. The cylindrical diffuser 20 has an approximately uniform light output in an outwardly dispersing cylindrical pattern with respect to the central axis 24 of the fiber 10.

The optical fiber 10 is a quartz optical fiber comprising a quartz core 14 with a diameter of 400 micron. The core 14 is covered by a jacket which consists of a cladding 13 and a sheathing 12. The core 14 is first clad with a transparent polymer layer 13 of 10-20 microns thick. The polymer is then protected from damage by another tefzel sheathing 12 with an outer diameter of about 860 microns. The outer diameter of the sheathing 12 may be changeable. However, the 860 micron diameter is useful because it is ideal to take a rolled thread in the standard size 000-120 (a watchmaker's size). This will be discussed in more detail hereafter. The length of the fiber 10 may be of about two meters long.

One of the ends of the optical fiber 10 is terminated in an SMA style connector (not shown) and connected (SMA to SMA) to a 10 meter length of 100 micron core intermediate jumper fiber which is otically coupled to the output of a laser, such as a 5mW HeNe laser.

At the opposite end of the optical fiber 10, the sheathing is removed by the use of a wire stripper tool and the cladding removed with the flame of a miniature

gas torch or by other proper methods so as to provide a bare core tip portion 15. The length of the bare core tip 15 is preferably 0.5 to 2.5 cm. However, longer lengths are also possible in particular applications.

The bare core tip portion 15 is then covered by a layer of scattering medium 16 which is composed of an optical adhesive; such as the Norland 61 or Epo-Tek 301 epoxy, and a powdered scatterer such as powdered synthetic sapphire (aluminum oxide), diamond dust or zirconium oxide dust. These scatters have refractive indexes to 630 nm light in the 1.7 to 2.2 range. Some other materials may also be suitable. However, the optical adhesive material should match the refractive index of the quartz (about 1.3) as closely as possible to avoid total internal reflection at the quartz-adhesive interface. The scatterer must be of different refractive index from the adhesive. To produce low loss diffusers it is important that the material used have minimal absorbance to the light in the wavelength range of the interested light source, and the adhesive and the powdered scattering material must be optically clear.

The bare core tip 15 is preferably coated with a thin layer of scattering medium 16. This can be accomplished by the following method. First, a thin film of optically clear adhesive is applied to the bare core tip 15. Then, a small artists brush is used to apply a scatterer to the surface of the adhesive-coated fiber core tip. The application of the scatterer is guided by the light transmitted in the fiber from a HeNe laser. During application, the fiber is held parallel to a sheet of white paper (about 1mm away from the surface). If the paper is between the fiber and the eye of the worker, a good idea of the uniformity of the light field can be obtained from the size and shape of the red illumination. When the desired result has been achieved, the adhesive is cured by UV light for the Norland #61 or by allowing it to cure in the case of the epoxy.

The mechanical requirements are satisfied by the use of a colorless, transparent sleeve 18 which is cylindrical in form and has a closed head portion 19. The sleeve 18 has a bore size larger than the diameter of the scatterer-coated core tip so as to provide an untouching match with the fiber tip and be suitable for being fixed on the jacket of the fiber 10 adjacent to the core tip portion 15. The sleeve 18 can be made of Lexan polycarbonate. In a preferred embodiment of the sleeve 18 as shown in Fig. 1, the sleeve 18 is in threaded connection with the jacket of the fiber 10. The Lexan cylinder (e.g. 1.8 mm outer diameter) is bored out to the diameter necessary for an 000-120 tap (#70 drill). The drill is carried to within 1 to 2 mm of the head portion 19. The cylinder is then tapped (000-120) to a depth of 3 millimeters. The bored length of the Lexan cylinder is at least 3 mm longer than the length of the bare core tip 15. The finished sleeve 18 is then threaded onto the jacket of the fiber 10. The jacket may have had a thread rolled onto it previously by the use of a metal die, or the sleeve 18 may be used to roll the thread at the time of installation. A small amount of epoxy applied to the threads of the sleeve 18 before installation will ensure a water tight seal and strengthen the connection. When properly installed, the sleeve 18 does not touch the scattering medium 16 as shown by a space 22, and thus the optical properties of the diffuser are unaffected by the sleeve 18 which protects the diffuser from mechanical stress during use. This design also makes it easy to manufacture and avoids the nonuniform light output caused by the uneven layer of scattering medium on the core tip which is possible in prior art devices.

Fig. 2 shows a preferred embodiment of the sleeve 18. The sleeve 18 has a sharpened head portion 19 The angle R of the tapered head 19 is between 30 and 90 degrees and is chosen to facilitate insertion of the fiber diffuser assembly through the endoscope and into a tumor.

This fiberoptic cylindrical diffuser has never failed in experimental use during over one hundred use cycles and has withstood repeated cold sterilization in gluteraldahyde solution ("Cydex") as well as gas sterilization.

As for a short fiberoptic diffuser (approximately 1 cm or less), an alternative of the present invention shown in Fig. 3 is to simply cleave fiber 10 and polish the bare core tip 15 to a flat square end face and then thread the sleeve 18 onto the fiber sheathing 12. The diffusing surface of the drilled out sleeve 18 scatters the light spreading out from the polished core end of the fiber 10. In this technique, the fiber is stripped and cleaved carefully so that only the very tip clears the jacket by a short distance, such as less than one mm.

Turning now to Figure 4, Figure 4 shows a fiberoptic spherical diffuser 30 of the present invention. The spherical diffuser 30 includes an optical fiber 10 with a bare core tip 15, a colorless bush member 35 with open ends circumferentially surrounding the core tip 15 and fixed on the jacket 11 of the fiber 10, and a spherical scattering medium 38 enclosing a portion of the bush member 35 and the core tip 15.

The optical fiber 10 still comprises a fiber core 14 protected by a jacket 11 which is composed of a cladding and a sheathing (not shown). The optical fiber 10 has a jacket-stripped tip portion 15, that is, a bare core tip.

The bush member 35 must have an absorbance as low as possible to the light in the wavelength range of interest. The bushing 35 can be made of Lexan polycarbonate. In a preferred embodiment, the bushing 35 is in a threaded connection with the jacket 11 of the fiber 10. The bushing 35 is tapped by using the 000-120 rolled thread technique as in the case of the cylindrical diffuser of the present invention. A difference is that the bushing member 35 has no closed end. In manufacture, the fiber end is cleaned and polished flat and square, and then threaded into a clear polycarbonate bushing 35 as shown by Figure 5. Figure 5 also shows an arrangement of the various sizes of the fiber-bushing assembly 34.

The scattering sphere 38 is composed of a clear optical adhesive and suspended scattering particle of the

powdered scattering material. As in the case of the cylindrical diffuser of the present invention, the best materials are those with the least absorbence at the wavelength of interest. Epoxy may be used as the optical adhesive. The index of refraction of the epoxy should match that of the quartz to minimize the reflective loss at the quartz epoxy interface. The epoxy can be any clear colorless product such as epo-tek 301. The sapphire powder, or other low loss scatterers such as diamond dust or powdered zirconia are suitable as the scattering material.

The exact proportions of scatter to epoxy depend upon several factors such as the overall diameter of the diffuser and the refractive index of the particles as well as their size. However, using the minimum amount of scattering material which provides the desired uniformity will result in the lowest loss and maximum power handling ability. The composition by weight preferably ranges between 5% and 20% scatterer, with 7% being about right for sapphire powder.

According to the present invention, the production of the sphere can be accomplished cheaply and efficiently by a molding technique employing a reusable silicon rubber mold to form the epoxy scattering sphere. The mold may include multiple cavities so that more than one spherical diffuser can be produced at the same time. As shown by Fig. 6, the silicon rubber mold containing many identical cavities can be produced from a chamber 41 for containing the melted silicon rubber 44 and a metal fixture (not shown) holding an array of identical metal molds of the finished bulb 42. One eighth inch bronze ball bearings bored out and press-filled to one sixteenth inch diameter stainless pin is one way to easily produce such a mold of the bulbs 42. After the silicon rubber has cured the metal plugs can be snapped out of the elastic molds without damage to the mold.

Referring now to Figure 7, the silicon rubber mold 45 is filled from the bottom up slowly by a pipet with the prepared epoxy-scatterer mixture 38 until it is filled completely, and the trapped air and bubbles are removed by tapping and squeezing the mold 45. Then, the finished fiber-bushing assembly 34 is held into the mold by an appropriate fixture and allowed to cure for a certain period at a predetermined temperature, such as two hours at 60° C. During curing of the mixture 38, the position of the end of the fiber 10 within the sphere can be precisely controlled. This is important because the symmetry of the light output depends upon the tip position. The light distribution may be fine tuned by adjusting the position of the fiber tip in the bushing.

In addition, the optical distribution of the diffuser is also related to the process of the pre-pour preparation of the scattering mixture 38. In one embodiment, the epoxy is first mixed with the sapphire for three minutes, then the mixture stands for one hour, mixed again for one minute and then the mixture is degased for 2 minutes with a vaccuum pump. The pre-pour curing time may be adjusted in order to get a better light distribution.

The symmetry and light distribution of a finished fiberoptic spherical diffuser can be measured by a turnable measuring device which includes a 5 mW HeNe laser source and a lock-in receiver with a digital volt meter.

While the preferred examples of the present invention have been shown and described, it should be apparent to those skilled in the art that many more modifications are possible without departing from the invention concept herein disclosed. It is intended to cover in the appended claims all such modifications as fall within the true scope of the invention.

Claims

1. A fiberoptic diffuser, comprising

   an optical fiber (10) with a fiber core (14) and a jacket (12, 13) for delivering light energy, a diffuser being arranged so that the pattern of radiated light is nearly uniform in intensity in a cylindrical pattern with respect to the central axis of said optical fiber (10), said optical fiber (10) including a jacket-stripped core tip portion (15), a sleeve means (18) enclosing said fiber tip portion (15) without touching the same and fixed on the fiber jacket (12, 13) adjacent to said fiber tip portion (15),

   characterized

   in that said sleeve means (18) has a closed end head portion (19) and an opened end portion fixed on the fiber jacket (12, 13) adjacent to said fiber tip portion (15) and

   in that said sleeve means (18) is in threaded connection with said fiber jacket (12, 13).

2. A fiberoptic diffuser in accordance with claim 1, wherein said fiber tip portion (15) is coated with a scattering medium (16).

3. A fiberoptic diffuser in accordance with claim 1 or 2, wherein said sleeve means (18) includes a bore size larger than the diameter of the fiber core (14) or the diameter of said scatterer-coated core tip (15, 16), and is in a cylindrical form with one end closed.

4. A fiberoptic diffuser in accordance with claim 1, wherein adhesive material is added on the threads of said sleeve means (18) or on the threads of the fiber jacket (12, 13) at the time of installation for ensuring a water-tight seal between said sleeve means (18) and said fiber jacket (12, 13).

5. A fiberoptic diffuser in accordance with claim 2, wherein said sleeve means (18) includes a closed cone-shaped head (19) at a desired angle with respect to the central axis of said optical fiber (10).

6. A fiberoptic diffuser in accordance with claim 2, wherein said scattering medium (16) is a composition of an optical adhesive material and a powdered scattering material.

7. A fiberoptic diffuser in accordance with claim 6, wherein the refractive index of said optical adhesive material is different from that of said powdered scattering material, the refractive index of said optical adhesive material matching the fiber core (14, 15), and wherein said powdered scattering material ranges between 5% and 20% by weight in said composition.

8. A fiberoptic diffuser in accordance with claim 7, wherein said powdered scattering material is selected from the group consisting of sapphire powder, i.e. aluminum oxide, or diamond dust or zirconium oxide dust.

9. A fiberoptic diffuser in accordance with claim 7 or 8, wherein said powdered scattering material is preferably in the range of 5% to 15% by weight in said composition.

10. A fiberoptic diffuser in accordance with claim 9, wherein said adhesive material is an epoxy.

11. A method for manufacture of a fiberoptic diffuser, comprising the steps of:

removing the cladding (13) and sheathing (12) of an optical fiber (10) at one end for a predetermined length for providing a bare core tip (15),
polishing said exposed bare core tip (15) for providing a clean and smooth surface,
choosing a colorless and transparent material to the light at a predetermined wavelength and making a desired shape thereby with a longitudinal size longer than the length of said bare core tip (15),
boring said shaped material with one end closed for providing a sleeve means (18),
inserting said bare core tip (15) into said sleeve means (18), and
fixing the open end of said sleeve means (18) on the fiber jacket (12, 13) adjacent to said bare core tip (15), wherein said fixing step includes the substeps of tapping threads on the inner surface of said sleeve means (18) and making threads on the surface of said fiber jacket (12, 13) in the portion adjacent to said bare core tip (15).

12. A method in accordance with claim 11, further including a step of optically homogeneously coating a thin layer of light scattering medium (16) on said polished bare core tip (15) with the outer diameter of the coated fiber tip smaller than the inner diameter of said sleeve means (18).

13. A method in accordance with claim 11 or 12, further including the step of tapering the closed end of said sleeve means (18) at a predetermined angle for providing a sharpened head (19).

14. A method in accordance with claim 11, wherein said fixing step includes the substep of adding adhesive material on said threads at the time of installation for providing a water-tight seal and strengthening the connection.

15. A spherical fiberoptic diffuser for dispersing light in a spherical scattering pattern, comprising

an optical fiber (10) with a jacket-stripped bare core tip (15) at one end, and
a scattering medium (38) enclosing said bare core tip (15) in a spherical form,
characterized
in that a cylindrical bushing means (35) is provided which circumferentially surrounds said bare core tip (15) without touching it and is fixed on the fiber jacket (11) adjacent to said bare core tip portion (15),
wherein said bushing means (35) is in threaded connection with said fiber jacket (11), and
in that said scattering medium (38) encloses and is in contact with a portion of said bushing means (35) and said bare core tip (15).

16. A spherical fiberoptic diffuser in accordance with claim 15, wherein said scattering medium (38) is a composition of an optical adhesive material and a powdered scattering material.

17. A spherical fiberoptic diffuser in accordance with claim 16, wherein said scattering medium (38) preferably comprises 5% to 20% powdered scattering material by weight.

18. A spherical fiberoptic diffuser in accordance with claim 17, wherein the refractive index of said optical adhesive material is different from that of said powdered scattering material, the refractive index of said optical adhesive material matching the fiber core (14, 15).

19. A spherical fiberoptic diffuser in accordance with claim 18, wherein said powdered scattering material is selected from the group consisting of sapphire powder, i.e. aluminum oxide, or diamond dust or zirconium oxide dust.

20. A spherical fiberoptic diffuser in accordance with

claim 18 or 19, wherein said powdered scattering material is preferably in the range of 5% to 15% by weight in said composition.

21. A spherical fiberoptic diffuser in accordance with claim 20, wherein said adhesive material is an epoxy.

22. A method for manufacturing a spherical fiberoptic diffuser radiating light in a spherical scattering pattern, comprising the steps of:

removing the cladding and sheathing of an optical fiber (10) at one end for a predetermined length for providing a bare core tip (15),
polishing said core tip (15) for providing a clean and smooth surface,
preparing a silicon rubber mold (45) including a round container portion and a cylindrical neck container portion,
slowly filling said mold (45) with a scattering mixture (38),
fixing a cylindrical bushing means (35) onto the jacket (11) of said fiber (10) which circumferentially surrounds said bare core tip (15), wherein said fixing step includes the substeps of making threads on the inner surface of said bushing means (35) and making threads on the surface of the fiber jacket (11) in the portion adjacent to said bare core tip (15),
inserting said fiber tip portion into said mold (45) filled with said scattering mixture (38), and
curing said scattering mixture (38) at a predetermined temperature.

23. A method in accordance with claim 22, further including a pre-pour step of preparing the scattering mixture (38) by the substeps of:

(i) mixing the adhesive material with the powdered scattering material for a predetermined time,
(ii) letting the mixture stand for a predetermined time, and
(iii) degasing said mixture with a vacuum pump for a predetermined time.

24. A method in accordance with claim 22, further including a step of adjusting the position of said fiber tip end in said filled mold (45) or a step of adjusting the position of said fiber tip in said bushing means (35).

Patentansprüche

1. Faseroptische Streueinrichtung, mit

einer optischen Faser (10) mit einem Faserkern (14) und einer Umhüllung (12, 13) zum Liefern von Lichtenergie, wobei eine Streueinrichtung so angeordnet ist, daß das Muster von abgestrahltem Licht in einem zylindrischen Muster in bezug auf die zentrale Achse der optischen Faser (10) in der Intensität nahezu gleichförmig ist, wobei die optische Faser (10) einen von der Umhüllung freien Kernspitzenabschnitt (15) aufweist,
einer Hülseneinrichtung (18), die den Faserspitzenabschnitt (15) umgibt, ohne ihn zu berühren, und benachbart zu dem Faserspitzenabschnitt (15) an der Faserumhüllung (12, 13) befestigt ist,
dadurch gekennzeichnet,
daß die Hülseneinrichtung (18) einen Kopfbereich (19) mit geschlossenem Ende und einen geöffneten Endbereich hat, der an der Faserumhüllung (12, 13) benachbart zu dem Faserspitzenabschnitt (15) befestigt ist, und
daß die Hülseneinrichtung (18) in einer geschraubten Verbindung mit der Faserumhüllung (12, 13) ist.

2. Faseroptische Streueinrichtung gemäß Anspruch 1, wobei der Faserspitzenabschnitt (15) mit einem Streumedium (16) beschichtet ist.

3. Faseroptische Streueinrichtung gemäß Anspruch 1 oder 2, wobei die Hülseneinrichtung (18) eine Bohrungsgröße größer als der Durchmesser des Faserkerns (14) oder der Durchmesser der mit einem Streumedium beschichteten Kernspitze (15, 16) aufweist und eine zylindrische Form mit einem geschlossenen Ende hat.

4. Faseroptische Streueinrichtung gemäß Anspruch 1, wobei zum Zeitpunkt der Montage Klebstoff auf die Gewindegänge der Hülseneinrichtung (18) oder auf die Gewindegänge der Faserumhüllung (12, 13) aufgebracht wird, um eine wasserdichte Versiegelung zwischen der Hülseneinrichtung (18) und der Faserumhüllung (12, 13) sicherzustellen.

5. Faseroptische Streueinrichtung gemäß Anspruch 2, wobei die Hülseneinrichtung (18) einen geschlossenen, kegelförmigen Kopf (19) unter einem gewünschten Winkel in bezug auf die Zentralachse der optischen Faser (10) aufweist.

6. Faseroptische Streueinrichtung gemäß Anspruch 2, wobei das Streumedium (16) eine Zusammensetzung aus einem optischen Klebmaterial und einem pulverisierten Streumaterial ist.

7. Faseroptische Streueinrichtung gemäß Anspruch 6, wobei der Brechungsindex des optischen Kleb-

materials von dem des pulverisierten Streumaterials verschieden ist, wobei der Brechungsindex des optischen Klebmaterials an den Faserkem (14, 15) angepaßt ist, und wobei das pulverisierte Streumaterial in der Zusammensetzung im Bereich zwischen 5 Gew.% und 20 Gew.% liegt.

8. Faseroptische Streueinrichtung gemäß Anspruch 7, wobei das pulverisierte Streumaterial ausgewählt ist aus der Gruppe, die aus Saphirpulver, d. h. Aluminiumoxid, oder Diamantstaub oder Zirkoniumoxidstaub besteht.

9. Faseroptische Streueinrichtung gemäß Anspruch 7 oder 8, wobei das pulverisierte Streumaterial vorzugsweise im Bereich von 5 Gew.% bis 15 Gew.% in der Zusammensetzung liegt.

10. Faseroptische Streueinrichtung gemäß Anspruch 9, wobei das Klebematerial ein Epoxidharz ist.

11. Verfahren zum Herstellen einer faseroptischen Streueinrichtung, mit den Schritten:

    Entfernen der Umkleidung (13) und Ummantelung (12) einer optischen Faser (10) an einem Ende über eine vorbestimmte Länge, um eine blanke Kernspitze (15) zu schaffen,
    Polieren der freigelegten blanken Kernspitze (15), um eine saubere und glatte Oberfläche zu schaffen,
    Auswählen eines für Licht bei einer vorbestimmten Wellenlänge farblosen und transparenten Materials und Herstellen einer gewünschten Form davon mit einer Längsgröße länger als die Länge der blanken Kernspitze (15),
    Ausbohren des geformten Materials, wobei ein Ende geschlossen ist, um eine Hülseneinrichtung (18) zu schaffen,
    Einsetzen der blanken Kernspitze (15) in die Hülseneinrichtung (18), und
    Befestigen des offenstehenden Endes der Hülseneinrichtung (18) an der Faserumhüllung (12, 13) benachbart zu der blanken Kernspitze (15), wobei der Befestigungsschritt die Unterschritte des Gewindeschneidens an der Innenfläche der Hülseneinrichtung (18) und des Gewindeherstellens an der Oberfläche der Faserumhüllung (12, 13) in dem der blanken Kernspitze (15) benachbarten Bereich einschließt.

12. Verfahren gemäß Anspruch 11, das ferner einen Schritt zum optisch homogenen Aufbringen einer dünnen Schicht eines Lichtstreumediums (16) auf der polierten, blanken Kernspitze (15) aufweist, wobei der äußere Durchmesser der beschichteten Faserspitze kleiner ist als der Innendurchmesser der Hülseneinrichtung (18).

13. Verfahren gemäß Anspruch 11 oder 12, das ferner den Schritt aufweist, das geschlossene Ende der Hülseneinrichtung (18) unter einem vorbestimmten Winkel konisch zu machen, um einen zugespitzten Kopf (19) zu schaffen.

14. Verfahren gemäß Anspruch 11, wobei der Befestigungsschritt den Unterschritt des Hinzufügens von Klebematerial auf die Gewindegänge zum Zeitpunkt der Montage aufweist, um eine wasserdichte Versiegelung und eine Verstärkung der Verbindung zu schaffen.

15. Sphärische faseroptische Streueinrichtung zum Zerstreuen von Licht in einem sphärischen Streumuster, mit

    einer optischen Faser (10) mit einer von einer Umhüllung befreiten blanken Kernspitze (15) an einem Ende, und
    einem Streumedium (38), das die blanke Kernspitze (15) in einer sphärischen Form umgibt, dadurch gekennzeichnet,
    daß eine zylindrische Hülseneinrichtung (35) vorgesehen ist, die die blanke Kernspitze (15) in Umfangsrichtung umgibt, ohne sie zu berühren, und an der Faserumhüllung (11) benachbart zu dem blanken Kernspitzenabschnitt (15) befestigt ist, wobei die Hülseneinrichtung (35) in geschraubter Verbindung mit der Faserumhüllung (11) ist, und
    daß das Streumedium (38) einen Teil der Hülseneinrichtung (35) und der blanken Kernspitze (15) umgibt und damit in Kontakt ist.

16. Sphärische faseroptische Streueinrichtung gemäß Anspruch 15, wobei das Streumedium (38) eine Zusammensetzung eines optischen Klebmaterials und eines pulverisierten Streumaterials ist.

17. Sphärische faseroptische Streueinrichtung gemäß Anspruch 16, wobei das Streumedium (38) vorzugsweise 5 Gew.% bis 20 Gew.% pulverisiertes Streumaterial aufweist.

18. Sphärische faseroptische Streueinrichtung gemäß Anspruch 17, wobei der Brechungsindex des optischen Klebmaterials von dem des pulverisierten Streumaterials verschieden ist, wobei der Brechungsindex des optischen Klebmaterials zu dem Faserkern (14, 15) paßt.

19. Sphärische faseroptische Streueinrichtung gemäß Anspruch 18, wobei das pulverisierte Streumaterial ausgewählt ist aus der Gruppe, die aus Saphirpul-

ver, d.h. Aluminiumoxid, oder Diamantstaub oder Zirkoniumoxidstaub besteht.

20. Sphärische faseroptische Streueinrichtung gemäß Anspruch 18 oder 19, wobei das pulverisierte Streumaterial vorzugsweise im Bereich von 5 Gew.% bis 15 Gew.% in der Zusammensetzung liegt.

21. Sphärische faseroptische Streueinrichtung gemäß Anspruch 20, wobei das Klebmaterial ein Epoxidharz ist.

22. Verfahren zum Herstellen einer sphärischen faseroptischen Streueinrichtung, die Licht in einem sphärischen Streumuster abstrahlt, mit den Schritten:

Entfernen der Umkleidung und Ummantelung einer optischen Faser (10) an einem Ende über eine vorbestimmte Länge, um eine blanke Kernspitze (15) zu schaffen,
Polieren der Kernspitze (15), um eine saubere und glatte Oberfläche zu schaffen,
Fertigen einer Silikonkautschukform (45), die einen Rundbehälterbereich und einen zylindrischen Halsbehälterbereich aufweist,
langsames Füllen der Form (45) mit einer Streumischung (38), Befestigen einer zylindrischen Hülseneinrichtung (35) an der Umhüllung (11) der Faser (10), die die blanke Kernspitze (15) in Umfangsrichtung umgibt, wobei der Befestigungsschritt die Unterschritte des Herstellens von Gewindegängen an der Innenfläche der Hülseneinrichtung (35) und des Herstellens von Gewindegängen an der Oberfläche der Faserumhüllung (11) in dem Bereich benachbart zu der blanken Kernspitze (15) aufweist,
Einsetzen des Faserspitzenabschnitts in die mit der Streumischung (38) gefüllte Form (45), und
Aushärten der Streumischung (38) bei einer vorbestimmten Temperatur.

23. Verfahren gemäß Anspruch 22, das ferner einen Schritt vor dem Gießen zum Bereiten der Streumischung (38) durch die Unterschritte

(i) Mischen des Klebmaterials mit dem pulverisierten Streumaterial für eine vorbestimmte Zeit,
(ii) Stehenlassen der Mischung für eine vorbestimmte Zeit, und
(iii) Entgasen der Mischung mit einer Vakuumpumpe für eine vorbestimmte Zeit
aufweist.

24. Verfahren gemäß Anspruch 22, das ferner einen Schritt des Einstellens der Position des Faserspitzenendes in der gefüllten Form (45) oder einen Schritt des Einstellens der Position der Faserspitze in der Hülseneinrichtung (35) aufweist.

Revendications

1. Diffuseur à fibre optique, comprenant

une fibre optique (10) ayant une âme en fibre (14) et une gaine (12, 13) pour délivrer l'énergie lumineuse, un diffuseur étant agencé de façon que le motif de lumière émise soit à peu près d'intensité uniforme dans un motif cylindrique par rapport à l'axe central de ladite fibre optique (10), ladite fibre optique (10) comprenant une partie de bout à âme dénudée (15),
un moyen formant manchon (18) enfermant ladite partie de bout de fibre (15) sans toucher cette dernière et fixée sur la gaine de fibre (12, 13) à côté de ladite partie de bout de fibre (15), caractérisé
en ce que ledit moyen formant manchon (18) possède une partie de tête d'extrémité fermée (19) et une partie d'extrémité ouverte fixée sur la gaine de fibre (12, 13) à côté de ladite partie de bout de fibre (15) et
en ce que ledit moyen formant manchon (18) est dans une relation filetée avec ladite gaine de fibre (12, 13).

2. Diffuseur à fibre optique selon la revendication 1, dans lequel ladite partie de bout de fibre (15) est revêtue d'un milieu diffusant (16).

3. Diffuseur à fibre optique selon la revendication 1 ou 2, dans lequel ledit moyen formant manchon (18) comporte un alésage de taille supérieure au diamètre de l'âme en fibre (14) ou au diamètre dudit bout d'âme revêtu de milieu diffusant (15, 16), et est de forme cylindrique avec une extrémité fermée.

4. Diffuseur à fibre optique selon la revendication 1, dans lequel une matière adhésive est ajoutée sur les filets dudit moyen formant manchon (18) ou sur les filets de la gaine de fibre(12, 13) au moment du montage pour assurer une étanchéité à l'eau entre ledit moyen formant manchon (18) et ladite gaine de fibre (12, 13).

5. Diffuseur à fibre optique selon la revendication 2, dans lequel ledit moyen formant manchon (18) comporte une tête fermée en forme de cône (19) à un angle souhaité par rapport à l'axe central de ladite fibre optique (10).

6. Diffuseur à fibre optique selon la revendication 2,

dans lequel ledit milieu diffusant (16) est une composition d'une matière adhésive optique et d'une matière diffusante en poudre.

7. Diffuseur à fibre optique selon la revendication 6, dans lequel l'indice de réfraction de ladite matière adhésive optique est différent de celui de ladite matière diffusante en poudre, l'indice de réfraction de ladite matière adhésive optique concordant avec la fibre optique (14, 15), et dans lequel ladite matière diffusante en poudre est comprise dans une plage de 5 % à 20 % en poids de ladite composition.

8. Diffuseur à fibre optique selon la revendication 7, dans lequel ladite matière diffusante en poudre est sélectionnée à partir du groupe constitué de poudre de saphir, c'est-à-dire d'oxyde d'aluminium, ou de poussière de diamant ou de poussière d'oxyde de zirconium.

9. Diffuseur à fibre optique selon la revendication 7 ou 8, dans lequel ladite matière diffusante en poudre est, de préférence, dans la plage de 5 % à 15 % en poids dans ladite composition.

10. Diffuseur à fibre optique selon la revendication 9, dans lequel ladite matière adhésive est un époxy.

11. Procédé pour fabriquer un diffuseur à fibre optique, comprenant les étapes suivantes :

l'enlèvement de la gaine (13) et du gainage extérieur (12) d'une fibre optique (10) à une extrémité particulière sur une longueur prédéterminée pour réaliser un bout d'âme dénudé (15),
le polissage dudit bout d'âme dénudé exposé (15) pour réaliser une surface propre et lisse,
le choix d'une matière incolore et transparente à la lumière à une longueur d'onde prédéterminée et fabrication d'une forme souhaitée, de ce fait, avec une taille longitudinale plus longue que la longueur dudit bout d'âme dénudé (15),
le forage de ladite matière formée avec une extrémité fermée pour réaliser un moyen formant manchon (18),
l'insertion dudit bout d'âme dénudé (15) dans ledit moyen formant manchon (18), et
la fixation de l'extrémité ouverte dudit moyen formant manchon (18) sur la gaine de fibre (12, 13) à côté dudit bout d'âme dénudé (15), dans laquelle ladite étape de fixation comprend les étapes secondaires de taraudage sur la surface intérieure dudit moyen formant manchon (18) et de fabrication de filets sur la surface de ladite gaine de fibre (12, 13) dans la partie adjacente audit bout d'âme dénudé (15).

12. Procédé selon la revendication 11, comprenant, de plus, une étape de revêtement d'une fine couche de milieu diffusant la lumière (16), de façon optiquement homogène, sur ledit bout d'âme dénudé poli (15), le diamètre extérieur du bout de fibre revêtu étant plus petit que le diamètre intérieur dudit moyen formant manchon (18).

13. Procédé selon la revendication 11 ou 12, comprenant, de plus, l'étape de formation en cône de l'extrémité fermée dudit moyen formant manchon (18) à un angle prédéterminé pour réaliser une tête pointue (19).

14. Procédé selon la revendication 11, dans lequel ladite étape de fixation comprend l'étape secondaire d'ajout d'une matière adhésive sur lesdits filets au moment du montage pour réaliser un joint étanche à l'eau et pour renforcer la connexion.

15. Diffuseur sphérique à fibre optique pour diffuser la lumière en un motif de diffusion sphérique, comprenant

une fibre optique (10) avec un bout d'âme dénudé, sans gaine, (15) à une extrémité, et
un milieu diffusant (38) enfermant ledit bout d'âme dénudé (15) sous une forme sphérique, caractérisé
en ce qu'un moyen formant douille cylindrique (35) est prévu, lequel entoure, de manière circonférentielle, ledit bout d'âme dénudé (15) sans le toucher et est fixé sur la gaine de fibre (11) à côté de ladite partie formant bout d'âme dénudé (15),
dans lequel ledit moyen formant douille (35) est en relation filetée avec ladite gaine de fibre (11), et
en ce que ledit milieu diffusant (38) enferme et est en contact avec une partie dudit moyen formant douille (35) et ledit bout d'âme dénudé (15).

16. Diffuseur sphérique à fibre optique selon la revendication 15, dans lequel ledit milieu diffusant (38) est une composition d'une matière optique adhésive et d'une matière diffusante en poudre.

17. Diffuseur sphérique à fibre optique selon la revendication 16, dans lequel ledit milieu diffusant (38) comprend, de préférence, 5 % à 20 % en poids de matière diffusante en poudre.

18. Diffuseur sphérique à fibre optique selon la revendication 17, dans lequel l'indice de réfraction de ladite matière adhésive optique est différent de celui de ladite matière diffusante en poudre, l'indice de réfraction de ladite matière adhésive optique

concordant avec la fibre optique (14, 15).

19. Diffuseur sphérique à fibre optique selon la revendication 18, dans lequel ladite matière diffusante en poudre est sélectionnée à partir du groupe constitué de poudre de saphir, c'est-à-dire d'oxyde d'aluminium, ou de poussière de diamant ou de poussière d'oxyde de zirconium.

20. Diffuseur à fibre optique selon la revendication 18 ou 19, dans lequel ladite matière diffusante en poudre est, de préférence, dans la plage de 5 % à 15 % en poids dans ladite composition.

21. Diffuseur sphérique à fibre optique selon la revendication 20, dans lequel ladite matière adhésive est un époxy.

22. Procédé pour fabriquer un diffuseur sphérique à fibre optique émettant de la lumière en un motif de diffusion sphérique, comprenant les étapes suivantes :

l'enlèvement de la gaine et du gainage extérieur d'une fibre optique (10) à une extrémité particulière sur une longueur prédéterminée pour réaliser un bout d'âme dénudé (15),
le polissage dudit bout d'âme (15) pour réaliser une surface propre et lisse,
la préparation d'un moule en caoutchouc de silicone (45) incluant une partie arrondie formant conteneur et une partie cylindrique en goulot formant conteneur,
le remplissage lent dudit moule (45) par un mélange diffusant (38),
la fixation d'un moyen formant douille cylindrique (35) sur la gaine (11) de ladite fibre (10) qui entoure, de manière circonférentielle, ledit bout d'âme dénudé (15), dans laquelle ladite étape de fixation comprend les étapes secondaires de fabrication de filets sur la surface intérieure dudit moyen formant douille (35) et de fabrication de filets sur la surface de ladite gaine de fibre (11) dans la partie adjacente audit bout d'âme dénudé (15),
l'insertion dudit bout d'âme dénudé dans ledit moule (45) rempli par ledit mélange diffusant (38), et
la cuisson dudit mélange diffusant (38) à une température prédéterminée.

23. Procédé selon la revendication 22, comprenant, de plus, une pré-étape de préparation du mélange diffusant (38) par les étapes secondaires suivantes :

(i) mélange de la matière adhésive avec la matière diffusante en poudre pendant un temps prédéterminé,
(ii) mise en repos du mélange pendant un temps prédéterminé, et
(iii) dégazage dudit mélange par une pompe d'aspiration pendant un temps prédéterminé.

24. Procédé selon la revendication 22, comprenant, de plus, une étape de réglage de la position de ladite extrémité de bout de fibre dans ledit moule rempli (45) ou une étape de réglage de la position dudit bout de fibre dans ledit moyen formant douille (35).

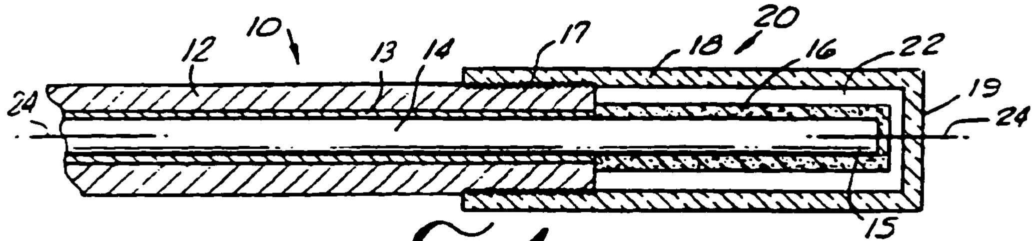

FIG.1.

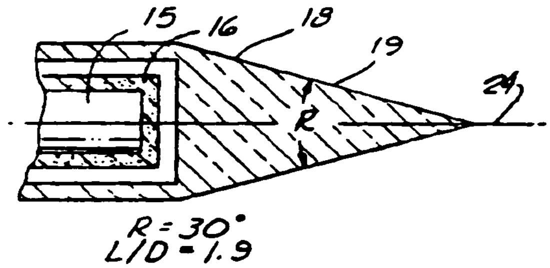

FIG.2A.

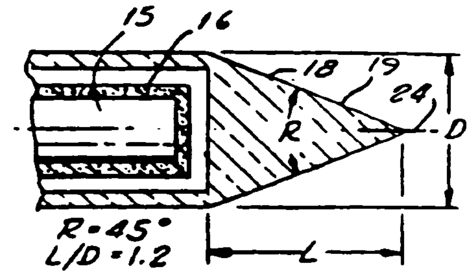

FIG.2B.

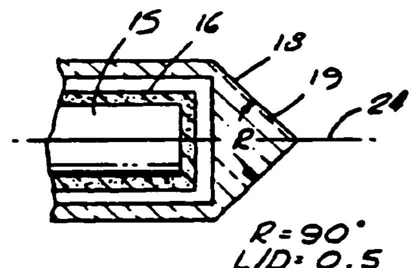

FIG.2C.

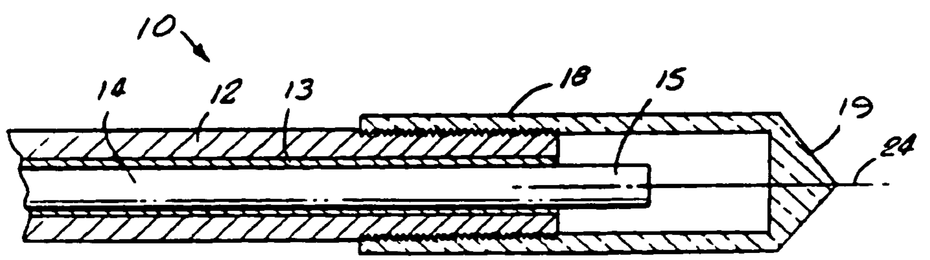

FIG.3.

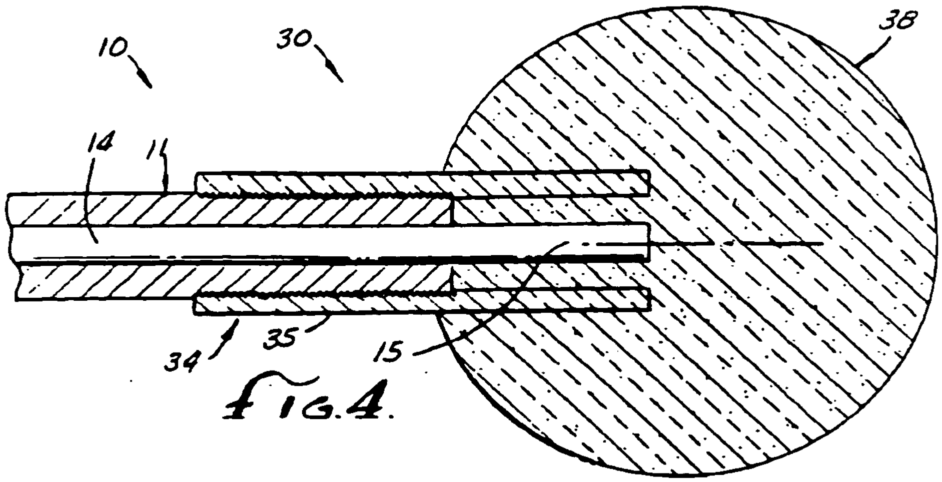

FIG.4.

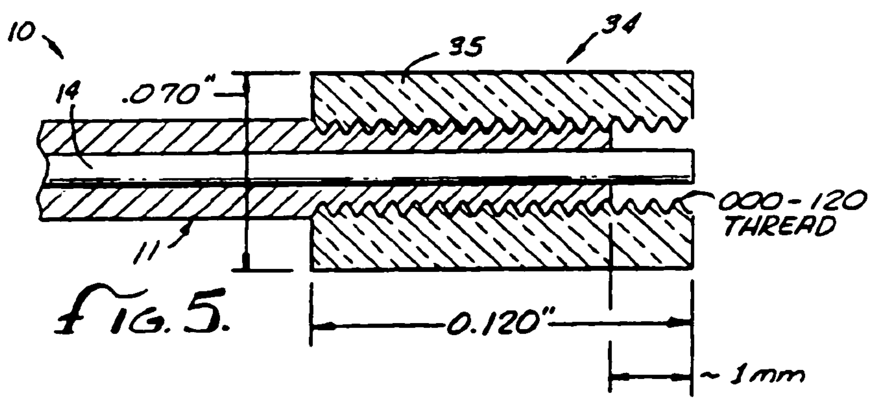

FIG.5.

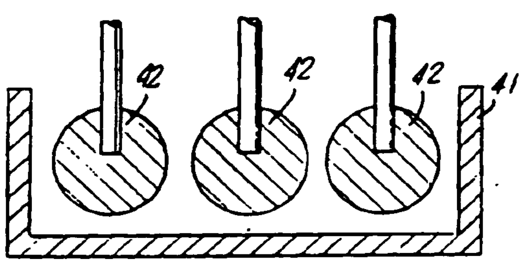

FIG.6.

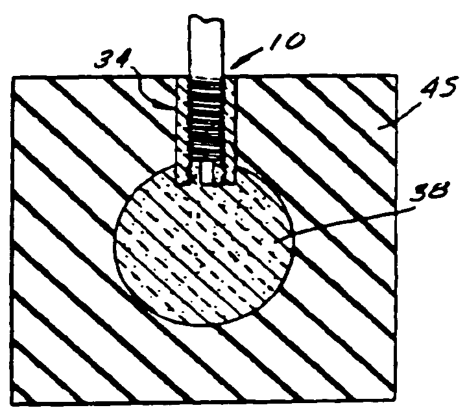

FIG.7.